CLAIMS

1. A process for forming a carbon- and transition metal-containing film on a surface of a substrate, comprising:

(a) placing the substrate into a reaction space;

(b) introducing a first chemical into the reaction space such that at least a portion of the first chemical is adsorbed onto the substrate surface;

(c) after introducing the first chemical, purging the reaction space;

(d) introducing a second chemical into the reaction space such that at least a portion of the second chemical reacts with the adsorbed first chemical to form the carbon- and transition metal-containing film, wherein the first chemical is one of a transition metal chemical and an organometallic chemical, and the second chemical is the other of the transition metal chemical and the organometallic chemical; and

(e) after the introducing the second chemical, purging the reaction space.

2. The process of claim 1, in which the first chemical is the transition metal chemical and the second chemical is the organometallic chemical.

3. The process of claim 1, further comprising:

introducing a third chemical into the reaction space such that at least a portion of the third chemical reacts with the carbon- and transition metal-containing film, wherein the third chemical includes a transition metal chemical or an organometallic chemical; and

after introducing the third chemical, purging the reaction space.

4. The process of claim 1, in which the first chemical is the organometallic chemical and the second chemical is the transition metal chemical.

5. The process of claim 1, in which the carbon- and transition metal-containing film has a thickness and in which steps (b) - (e) comprise a first cycle, and in which the first cycle is repeated one or more times to increase the thickness of the carbon- and transition metal-containing film.

6. The process of claim 5, in which the first cycle is repeated between 1 and 10,000 times.

7. The process of claim 1, in which the transition metal chemical includes a transition metal portion and a non-metal portion.

8. The process of claim 7, in which the non-metal portion is a halide.

9. The process of claim 8, in which the halide is a chloride.

10. The process of claim 7, in which the transition metal portion is selected from the group consisting essentially of titanium, zirconium, hafnium, vanadium, niobium, tantalum, chromium, molybdenum, and tungsten.

11. The process of claim 1, in which the transition metal chemical is selected from the group consisting essentially of titanium trichloride, titanium tetrachloride, titaniumtetraiodate, zirconium tetrachloride, zirconium tetraiodate, hafnium tetrachloride, hafnium tetraiodate, niobium pentachloride, tantalum pentachloride, molybdenum pentachloride, tungsten hexachloride, and tungsten hexafluoride.

12. The process of claim 1, in which the transition metal chemical includes a mixture of transition metal chemicals including at least two different transition metals.

13. The process of claim 12, in which each of the at least two different transition metals in the mixture of transition metal chemicals is present in a proportion of at least 1 atomic percent.

14. The process of claim 12, in which the transition metal chemical includes at least two different transition metals that are alternately introduced into the reaction space.

15. The process of claim 1, in which the organometallic chemical includes an organic portion and a metal portion.

16. The process of claim 15, in which the metal portion is selected from the group consisting essentially of aluminum, gallium, and a transition metal.

17. The process of claim 15, in which the organic portion is selected from the group consisting essentially of an alkyl group ligand and a substituted alkyl ligand.

18. The process of claim 17, in which the alkyl group ligand is selected from the group consisting essentially of methyl, ethyl, i-butyl, butyl, i-propyl, and cyclopentadienyl.

19. The process of claim 1, in which the organometallic chemical is trimethylaluminum.

20. The process of claim 1, in which the organometallic chemical includes a halide portion.

21. The process of claim 20, in which the organometallic chemical is dimethylaluminum chloride.

22. The process of claim 1, in which the transition metal chemical includes a transition metal portion and a non-metal portion and the organometallic chemical

includes an organic portion and a metal portion, and the metal portions of the organometallic chemical and the transition metal chemical are the same metal.

23. The process of claim 1, in which the substrate includes a previously formed film.

24. The process of claim 23, in which the previously formed film is patterned.

25. The process of claim 1, in which the substrate is placed into the reaction space such that both sides of the substrate are exposed to the first and second chemicals.

26. The process of claim 1, in which the substrate is positioned in the reaction space such that it is at least partially shielded to hinder formation of the carbon- and transition metal-containing film on at least a portion of the substrate.

27. The process of claim 1, in which more than one substrate is placed into the reaction space such that the carbon- and transition metal-containing film forms on at least one surface of each substrate.

28. The process of claim 1, in which the transition metal chemical includes a transition metal portion and a non-metal portion and the organometallic chemical includes an organic portion and a metal portion, and the metal portions of the organometallic chemical and the transition metal chemical are different metals.

29. The process of claim 1, in which the purging of the reaction space includes purging with an inert gas selected from the group consisting essentially of nitrogen, helium, neon, argon, carbon dioxide, and mixtures thereof.

30. The process of claim 1, in which the substrate is selected from the group consisting essentially of glass, silica, silicon, metals, alloys, fibers, ceramics, porous materials, mixtures thereof, and layers thereof.

31. The process of claim 1, in which the reaction space is operated at atmospheric pressure.

32. The process of claim 1, in which the reaction space is operated at a pressure that is less than atmospheric pressure.

33. The process of claim 1, in which the reaction space is operated at a pressure that is between about 0.1 mbar and about 50 mbars.

34. The process of claim 1, in which the reaction space is heated.

35. The process of claim 1, in which the reaction space is operated at a temperature that is between about 150°C and about 600°C.

36. The process of claim 1, in which the reaction space is operated at a temperature that is between about 250°C and about 550°C.

37. The process of claim 1, in which the reaction space is within an atomic layer deposition reactor.

38. The process of claim 1, in which the carbon- and transition metal-containing film has a thickness and in which steps (b) – (e) comprise a first cycle, the process further including a second cycle comprising:

introducing a third chemical into the reaction space such that at least a portion of the third chemical reacts with the carbon- and transition metal-containing film;

after introducing the third chemical, purging the reaction space;

introducing a fourth chemical into the reaction space such that at least a portion of the fourth chemical reacts with a portion of the third chemical to form a second carbon- and transition metal-containing film, and wherein the third chemical is one of a transition metal chemical and an organometallic chemical, and the fourth chemical is the other of the transition metal chemical and the organometallic chemical; and

after introducing the fourth chemical, purging the reaction space.

39. The process of claim 38, in which the first cycle and the second cycle are performed in a ratio of between about 50:1 and about 1:50.

40. The process of claim 38, in which the first cycle and the second cycle are alternately and sequentially performed n times where n is an integer between 1 and 10,000.

41. The process of claim 38, in which the first cycle is repeated n times where n is an integer between 1 and 10,000 followed by repetition of the second cycle n times where n is an integer between 1 and 10,000.

42. The process of claim 1, in which the first chemical adsorbed onto the substrate surface forms a monolayer.

43. The process of claim1, in which the first chemical adsorbed onto the substrate surface forms less than a monolayer.

44. The process of claim 1, in which the carbon- and transition metal-containing film is a transition metal carbide.

45. The process of claim 1, in which one of the organometallic chemical and the transition metal chemical is introduced into the reaction space via an inert carrier

gas selected from the group consisting essentially of nitrogen, helium, neon, argon, neon, carbon dioxide, or a mixture thereof.

46. The process of claim 1, in which at least one of the first chemical or the second chemical is in the form of a vapor.

47. The process of claim 1, in which the transition metal chemical includes a transition metal portion, and in which the carbon- and transition metal-containing film includes at least 25 atomic percent of the transition metal portion.

48. The process of claim 1, in which the organometallic chemical includes an organic portion and a metal portion, and in which the carbon- and transition metal-containing film includes between about 0 and about 20 atomic percent of the metal portion.

49. The process of claim 1, in which the transition metal chemical includes a transition metal portion and a non-metal portion and the organometallic chemical includes an organic portion and a metal portion, and in which the carbon- and transition metal-containing film includes at least 25 atomic percent of the transition metal portion, at least 30 atomic percent of the organic portion, less than 20 atomic percent of the metal portion from the organometallic chemical, and less than 10 atomic percent of an impurity.

50. The process of claim 49, in which the organic portion is carbon.

51. The process of claim 1, in which the carbon- and transition metal-containing film includes less than 25 atomic percent of a mixture including residual metals and impurities.

52. The process of claim 1, in which the carbon- and transition metal-containing film includes less than 15 atomic percent of a mixture including halides and impurities.

53. The process of claim 1, in which the carbon- and transition metal-containing film includes less than 10 atomic percent of a nitrogen-containing impurity.

54. The process of claim 1, in which the carbon- and transition metal-containing film has a nonuniformity of sheet resistance that is less than 20%.

55. The process of claim 1, in which the carbon- and transition metal-containing film is deposited by an atomic layer deposition method.

56. The process of claim 1, in which the carbon- and transition metal-containing film is patterned.

57. The process of claim 1, in which the transition metal chemical reacts with the surface of the substrate to form a surface bound transition metal complex.

58. The process of claim 1, in which the carbon- and transition metal-containing film is selected from the group consisting essentially of titanium carbide, zirconium carbide, hafnium carbide, niobium carbide, tantalum carbide, molybdenum carbide, and tungsten carbide.

59. The process of claim 1, in which an inert gas flows through the reaction space.

60. The process of claim 1, in which the carbon- and transition metal-containing film has a film thickness nonuniformity of less than 20%.

61. The process of claim 1, further comprising depositing by atomic layer deposition a layer of a metal nitride, silicon nitride, or germanium nitride film.

62. The process of claim 1, further comprising depositing by atomic layer deposition a layer of a metal oxide, silicon oxide, or germanium oxide film.

63. The process of claim 1, further comprising depositing by atomic layer deposition a layer of a metal, silicon, or germanium film.

64. A carbon- and transition metal-containing film produced by the process of claim 1.

65. The carbon- and transition metal-containing film of claim 64, in which the film forms one of the group consisting essentially of a conductive diffusion barrier, a corrosion protection layer, a chemical reaction catalyst, a hard wear-resistant coating, an etch stopper for use in a patterning process, a dielectric film, a conductive film, and a diffusion barrier layer.

66. A carbon- and transition metal-containing film formed on a surface of a substrate such that the film includes less than 0.1 atomic percent of a contaminant selected from the group consisting essentially of boron, silicon, or phosphorus.

67. The carbon- and transition metal-containing film of claim 66, in which the film has a thickness between about 0.5 nm and about 100 nm.

68. The carbon- and transition metal-containing film of claim 66, in which the film includes a transition metal selected from the group consisting of titanium, zirconium, hafnium, vanadium, niobium, tantalum, chromium, molybdenum, and tungsten.

69. A reactor for forming a carbon- and transition metal-containing film on a surface of a substrate, comprising:

a reaction space into which the substrate is placed;

a first source system for delivering to the reaction space a first chemical;

a second source system for delivering to the reaction space a second chemical, wherein the first chemical is one of a transition metal chemical or an organometallic chemical and the second chemical is the other of the transition metal chemical or the organometallic chemical;

an inert gas flow system for delivering to the reaction space an inert gas;

a heating system for heating the reaction space; and

a control system operatively coupled to the first and second source systems for controlling the delivery of the chemicals into the reaction space.

70. A process for forming a carbon- and transition metal-containing film on a surface of a substrate, comprising:

placing the substrate into the reaction space;

introducing a starting pulse chemical into the reaction space such that at least a portion of the starting pulse chemical is adsorbed onto the substrate surface; and

introducing a first chemical and a second chemical into the reaction space in an alternating sequence such that at least a portion of the first chemical and at least a portion of the second chemical react to form the carbon- and transition metal-containing film, wherein the first chemical is one of a transition metal chemical and an organometallic chemical, and the second chemical is the other of the transition metal chemical and the organometallic chemical.

71. The process of claim 70, in which the starting pulse chemical includes an organometallic precursor chemical, the first chemical includes a transition metal chemical, and the second chemical includes an organometallic chemical.

72. The process of claim 70, in which the starting pulse chemical includes a transition metal precursor, the first chemical includes an organometallic chemical, and the second chemical includes a transition metal chemical.

73. The process of claim 70, in which the reaction space is purged before the introduction of each of the first and second chemicals.